Association of Adolescent Sport Participation With Cognition and Depressive Symptoms in Early Adulthood

Adam D. Bohr,*† PhD, Jason D. Boardman,‡ PhD, and Matthew B. McQueen,† ScD

Investigation performed at the University of Colorado Boulder, Boulder, Colorado, USA

Background: Recent studies have associated sport-related concussion with depression and impaired cognitive ability later in life in former professional football players. However, population studies with two 1950s-era cohorts did not find an association between high school football participation and impaired cognition or depressive symptoms in late adulthood.

Purpose/Hypothesis: This study assessed whether actual/intended participation in contact sports during adolescence had an adverse effect on participants' cognition or depressive symptoms in early adulthood. We hypothesized that there would not be an association.

Study Design: Cohort study; Level of evidence, 2.

Methods: This study used a subsample (n = 10,951) from the National Longitudinal Study of Adolescent to Adult Health (Add Health), a nationally (United States) representative prospective cohort study following participants through 4 waves of data collection from 1994 through 2008. Participants were categorized as actual/intended participation in no sports, noncontact sports only, and contact sports. We constructed 6 multivariate and logistic regression models predicting word recall, number recall, modified Center for Epidemiologic Studies Depression Scale, depression diagnosis, suicide ideation, and suicide attempts at wave IV as a function of sport participation during wave I. Sport participation was treated as a factor with the referent category noncontact sports. This analysis was repeated on a males-only sample (n = 5008). In the males-only analysis, participants were classified as actual/intended participation in no sports, noncontact sports, contact sports other than American football, and American football. The referent category remained noncontact sports.

Results: Intention to participate in contact sports was not significantly associated with any of the outcomes in the full-sample analysis. Intention to participate in football was significantly associated with a reduced odds of depression diagnosis in adulthood (odds ratio, 0.70; $P = .02$) when compared with noncontact sports participation in the males-only sample. Football was not significantly associated with impaired cognitive ability, increased depressive symptoms, or increased suicide ideation.

Conclusion: Actual/intended participation in contact sports during adolescence did not adversely affect Add Health participants' cognition or depressive symptoms in young adulthood.

Keywords: football (American); statistics; head injuries/concussion; epidemiology

Recent studies have associated sport-related concussion with depression and impaired cognitive ability later in life among former professional football players.[11,12,16] Additionally, early exposure to tackle football has been linked with earlier onset of chronic traumatic encephalopathy, leading some to question the safety of the youth game.[1,2,27] However, others argue that participation in contact sports, concussion, the development of chronic traumatic encephalopathy, and downstream adverse effects have been conflated, although there is little evidence of a causal link among them.[8,25]

While former professional players have been studied extensively, there have been fewer studies investigating the link between participation in contact sports such as football during adolescence and impaired cognitive ability and/or depression in adulthood. The studies that do exist have generated conflicting results. Montenigro et al[29] developed a cumulative head impact index and identified a relationship with increased head impact exposure to depression and later-life cognitive impairment in high school and college football players. However, in population studies, Savica et al[35] and Deshpande et al[10] did not find an association between football and impaired cognition or depressive symptoms in adulthood in two 1950s-era cohorts.

Our study focused on the association between intended participation in contact sports during adolescence and subsequent later-life depression as well as impaired cognitive

The Orthopaedic Journal of Sports Medicine, 7(9), 2325967119868658
DOI: 10.1177/2325967119868658

ability in a more recent cohort. The National Longitudinal Study of Adolescent to Adult Health (Add Health) was chosen for analysis because of its longitudinal prospective nature, nationally (United States) representative sample, and wide range of demographic, economic, and health-related controls. We hypothesized that intention to participate in contact sports during adolescence will not adversely affect participants' cognitive or mental health in early adulthood.

METHODS

Sample

The study utilized a sample of individuals from Add Health,[14] a longitudinal study that investigates how social and environmental factors may influence health. It has followed a cohort of individuals through 5 waves of interviewing and testing since the 1994-1995 school year. Add Health employed a school-based clustered sampling strategy from a sampling frame of 80 nationally representative high schools. The initial in-school survey, completed during the 1994-1995 school year, was administered to >90,000 students. All students who participated in the in-school interview were eligible for participation in the in-home interview. Roughly 17 students per stratum were selected for participation. The current study uses elements from both the in-school and the in-home interviews.

The full Add Health study consisted of 20,792 individual participants and >8500 measures/assessments. Participants were roughly 16 years of age in wave I (W1) and 29 years old by wave IV (W4). However, our criteria for model generation reduced the final analytic sample substantially. First, measurement of all primary outcomes was contingent on participants taking part in the W4 interviews. Selecting only participants with data from W4 reduced the analysis sample to 15,701. Additionally, while general sports and activity measures were taken at the W1 and wave II (W2) in-home interviews, sport-specific questions were only part of the W1 in-school interview. Not all W4 participants were part of these interviews, and restricting to participants with responses to the W1 in-school interview sport participation questions further reduced our sample to 11,682. Residual missingness in outcome or primary predictor variables reduced our final sample to 10,951.

Data

Sport Participation. A complete list of the source variables used for analysis is available in Appendix Table A1. Sport participation was determined with methods similar to previous research.[24] During the W1 in-school interviews, students were presented with the following statement: "Here is a list of clubs, organizations, and teams found at many schools. Darken the oval next to any of them you are participating in this year, or that you plan to participate in later in the school year." Variates for the following sports were included in analysis for this study: field hockey, American football, ice hockey, soccer, wrestling, baseball, basketball, swimming, tennis, track, volleyball, and other. Using these variables, we created a sport participation construct by grouping participants who intended to participate in contact sports, noncontact sports only, and no sports. Contact sports consisted of American football, field hockey, ice hockey, soccer, and wrestling. Noncontact sports only consisted of baseball, basketball, swimming, tennis, track, volleyball, and other. As American football is an almost exclusively male sport, we also performed analysis in a males-only sample with the following sport classifications: football, contact sports other than football, noncontact sports only, and no sports.

Outcome Measures. Our primary outcomes were word recall, number recall, depression diagnosis, suicide ideation, suicide attempts, and a modified Center for Epidemiologic Studies Depression Scale (CES-D) at W4. Word recall was measured by giving participants a list of words and asking them to recall as many as possible after a 90-second period. Number recall was measured by performing a similar task with a series of numbers. Previous studies used the Add Health Picture Vocabulary Test to measure cognition at W1.[18,21] However, as this test was not done at W4 and word and number recall are classified as "cognitive" in the Add Health Codebook Explorer, we relied on these variables instead. Responses to 3 questions from the W4 interviews served as measures of suicide ideation, suicide attempts, and depression diagnosis. Participants were asked, "Have you ever seriously thought about committing suicide?" and "How many times have you actually attempted suicide?" in the previous 12 months. Recorded responses for suicide ideation at W1 and W4 were "no," "yes," "legitimate skip," "refused," "missing," and "don't know." Ambiguous responses for this question accounted for <1% of responses in the full data set and were coded as missing. However, for the question on suicide attempts at W1, "legitimate skip" accounted for 86.75% of the total responses. As such, it was assumed that

*Address correspondence to Adam D. Bohr, PhD, Department of Integrative Physiology, University of Colorado Boulder, 354 UCB, Boulder, CO 80309, USA (email: adam.bohr@colorado.edu).
† Department of Integrative Physiology, University of Colorado Boulder, Boulder, Colorado, USA.
‡ Department of Sociology and Institute of Behavioral Science, University of Colorado Boulder, Boulder, Colorado, USA.
The content is solely the responsibility of the author and does not necessarily represent the official views of the CU Population Center, NIH, or CU Boulder.
One or more of the authors has declared the following potential conflict of interest or source of funding: This research has benefited from research, administrative, and computing support provided by the University of Colorado Population Center (Project 2P2CHD066613-06), funded by the Eunice Kennedy Shriver National Institute of Child Health and Human Development. Publication of this article was funded by the University of Colorado Boulder Libraries Open Access Fund. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.
Ethical approval for this study was waived by the University of Colorado Boulder Institutional Review Board.

these were participants who had not attempted suicide, and they were treated as such for our analysis. Additionally, while this question asked how many times a participant had attempted suicide, all individuals who had attempted suicide were grouped to create a binary variable for logistic regression analysis. During the W4 interviews, participants were also asked, "Has a doctor, nurse, or other health care provider ever told you that you have or had depression?" Responses to this question were simple yes/no.

The CES-D is a 20-question self-administered assessment that measures depressive symptoms.[33] However, research has indicated that the full assessment may not be valid in measuring depressive symptoms in different races and that a modified version with only 5 of the questions is more appropriate for comparison across racial/ethnic groups.[30] Four of the 5 questions were asked in both W1 and W4 and were used to create our modified CES-D. Our CES-D ranged from 0 to 12, with higher scores indicating greater depressive symptoms. A full description of the CES-D construct is presented in the Appendix and Appendix Table A2.

Control Measures. Variables for sex, age at W1 and W4, race, socioeconomic status, and early-life constructs for the outcome variables were extracted to serve as controls in the analytical models. W1 "BIO_SEX" was used for sex. W1 age was constructed by subtracting the 15th day of the participant's birth month and year from the W1 interview date. W4 age was extracted from the variable "AGE_W4." Self-reported race and ethnicity were assigned with the Add Health variable "AH_RACE." Participants identified as "white," "African American," "Native American," "Asian," "Hispanic," or "missing."

A multivariate approach was taken to control for socioeconomic status by accounting for education of the participant, parent, and parent spouse. These variables were categorical and were grouped by "less than high school," "high school," "some college," "college grad," "post grad/baccalaureate," and "missing." Additionally, we utilized the Add Health Contextual Data to extract the rate of persons older than 25 years with a college degree at the census tract level and included it as a control.

Finally, we attempted to incorporate a W1 proxy for each of our 6 W4 outcomes into our models as early-life controls. There were exact W1 proxies for suicide ideation, suicide attempts, and CES-D at W4. However, depression diagnosis was not assessed at W1, and the 2 cognitive recall tests from W4 were not implemented. As such, we used the W1 CES-D as a proxy for W1 depression diagnosis and the standardized score from the W1 Add Health Picture Vocabulary Test as a proxy for W1 cognitive ability.

Data Analysis

We constructed regression models for each of our 6 outcomes using the sample of complete cases described. Generalized linear models were used to predict CES-D, word recall, and number recall at W4. Logistic regression models were used to predict depression diagnosis, suicide ideation, and suicide attempts at W4. The W1 proxies described here were used as early-life controls for each of the 6 outcomes. Sex, age at W1 and W4, race, neighborhood college graduation rate, and education of participants, parents, and parent spouses were included as controls in all models. Race was analyzed as a factor, comparing the groups "African American," "Hispanic," "Asian," "Native American," and "missing" with the referent group "white." Participant, parent, and parent spouse education levels were also analyzed as factors, comparing "less than high school," "high school," "some college," "post grad/baccalaureate," and "missing" with the referent group "college grad." The primary explanatory variable of interest in all models was intended sport participation. In the full-sample models, the no sports and contact sports groups were compared with the referent group noncontact sports only. In the males-only sample, the no sports, contact sports other than football, and football groups were compared with the referent group noncontact sports only.

In addition to linear and logistic regression models, we conducted ancillary analyses to determine if selection bias may have affected our results. Specifically, we designed analyses to determine if those who intended to participate in contact sports during W1 of the study may have been more likely to select out of the sample by W4. First, we performed χ^2 goodness-of-fit analysis to determine if the distribution of sport participation in W1 was different from the distribution among W4 participants. Additionally, we ran a 2-way analysis of variance comparing the grade point average (GPA) of respondents in W1 and W4 as a function of sports participation to assess if those with the lowest GPA were most likely to select out of the study as a function of their sports. Last, we constructed a logistic regression model predicting selection out of the study by W4 as a function of our sport participation construct and the previously described controls for age, sex, race, and education. All analyses were done with RStudio (v 3.5.1).[34]

RESULTS

Table 1 presents descriptive statistics for the full sample stratified by sex. Our sample consisted of 45.7% males and 54.3% females. Sport participation was 53.8%, 62.4%, and 46.5% in our full, males-only, and females-only samples, respectively. Football participation in the males-only sample was 26.0%. Mean ± SD ages of all participants at W1 and W4 were 16.1 ± 1.6 years and 29.0 ± 1.7 years.

Figure 1 displays an unadjusted comparison of all outcome measures across sport groups. The results of the linear and logistic regression models for primary explanatory variables are presented in Tables 2 and 3. We report R^2 and root mean square error as measures of model fit for our linear regression models and 95% CIs for odds ratios (ORs) from our logistic regression models. Conversion of ORs to risk ratios is available in Appendix Table A3. In all models, W1 proxies were significant ($P < .001$) positive predictors of the W4 outcomes. All other factors being equal, an increase in W1 CES-D was associated with an increase in W4 CES-D, and an increase in W1 Add Health Picture Vocabulary Test was associated with increased scores on the word recall and number recall. Similarly,

TABLE 1
Participant Descriptive Statistics: Add Health Study (1994-2008)[a]

	Full Sample		Males Only		Females Only	
	n	%	n	%	n	%
Sex						
Male	5008	45.7	5008	100.0	—	—
Female	5943	54.3	—	—	5943	100.0
Race						
African American	2459	22.5	993	19.8	1466	24.7
Asian	689	6.3	357	7.1	332	5.6
Hispanic	1665	15.2	775	15.5	890	15.0
Native American	84	0.8	36	0.7	48	0.8
White	6031	55.1	2832	56.5	3199	53.8
Missing	23	0.2	15	0.3	8	0.1
Actual/intended sport participation						
No sports	5063	46.2	1886	37.7	3177	53.5
Noncontact sports	3527	32.2	1285	25.7	2242	37.7
Contact sports	972	8.9	534	10.7	438	7.4
Football	1389	12.7	1303	26.0	86	1.4
Suicide ideation						
Wave I	1474	13.5	493	9.8	981	16.5
Wave IV	705	6.4	283	5.7	422	7.1
Suicide attempts						
Wave I	398	3.6	103	2.1	295	5.0
Wave IV	126	1.2	52	1.0	74	1.2
Wave IV depression diagnosis	1638	15.0	458	9.1	1180	19.9
	Mean	SD	Mean	SD	Mean	SD
Age, y						
Wave I	16.1	1.7	16.2	1.7	16.0	1.7
Wave IV	29.0	1.7	29.1	1.7	28.9	1.7
CES-D						
Wave I	2.4	2.3	2.0	1.9	2.7	2.5
Wave IV	2.1	2.2	1.9	2.0	2.2	2.3
Wave I						
Picture Vocabulary Test	101.3	14.3	102.5	14.3	100.5	14.2
Wave IV						
90-s word recall	6.7	2.0	6.4	1.9	7.0	2.0
Number recall	4.2	1.5	4.3	1.5	4.2	1.5

[a]Complete cases only (n = 10,951). CES-D, Center for Epidemiologic Studies Depression Scale.

an increase in W1 CES-D was associated with increased odds of depression diagnosis at W4, and increases in W1 suicide ideation and attempts were associated with increased odds of suicide ideation and attempts at W4. These effects were consistent in both the full analytic sample and the males-only subsample.

Results for sport participation were more varied. All reported analysis is compared with the referent group, noncontact sports only. In full-sample analysis, the no sports category was associated with lower number recall ($b = –0.06$, $P = .04$) as well as increased odds of depression (OR = 1.22, $P < .01$) and suicide ideation (OR = 1.35, $P < .01$). Sport participation was not significantly associated with any other outcomes in full-sample analyses, although contact sports were trending toward an association with increased odds of suicide attempt (OR = 1.68, $P < .07$).

In males-only sample analysis, the no sports category was associated with lower number recall ($b = –0.11$, $P = .04$) than the referent group noncontact sports. Football was associated with reduced odds of depression (OR = 0.70, $P = .02$) than the referent group noncontact sports. Sport participation was not significantly associated with any of the other outcome variables, although the no sports category was trending toward increased odds of depression diagnosis (OR = 1.24, $P = .09$).

Results of ancillary analyses on selection bias are available in Appendix Tables A4 and A5. We did not find a statistically significant difference in the distribution of intended sport participation between W1 and W4 ($\chi^2 = 3.08$, $P = .38$). Similarly, GPA as a function of intended sport participation did not differ between W1 and W4 ($F = 2.02$, $P = .16$). Finally, intended participation in contact sports (OR = 0.96, $P = .73$) was not significantly associated with selection out of the study by W4.

Results for other covariates are found in Table 4.

DISCUSSION

Intended participation in contact sports was not significantly associated with any of our outcomes in the full-sample analysis, although it was trending toward an association with suicide attempt. Participants who played/intended to play football also had significantly reduced odds of depression diagnosis in adulthood when compared with noncontact sports participation in the males-only sample. Football was not significantly associated with impaired cognitive ability, increased depressive symptoms, or increased suicide ideation.

Broadly, our results reflect those of several recent studies that failed to find an association between participation in football during high school or college and a host of adverse cognitive and mental well-being outcomes.[10,17,35] Most recently Deshpande et al[10] found no association between participation in high school football and either reduced cognitive ability or increased CES-D scores from a cohort of 1950s-era Wisconsin football players. Their study reflected the findings of Savica et al[35] and Janssen et al,[17] who found no links between high school football participation and later-life neurodegeneration in a similar cohort from Rochester, Minnesota. Collectively, these studies with ours represent 3 cohorts in different geographical locations, capture several generations of football players, represent age groups from 28 to 70 years, and fail to find associations between playing football and a multitude of adverse outcomes in adulthood. Our findings for suicide ideation and attempts are consistent with prior research that did not identify an increased risk of suicidality in former athletes.[3,22,23]

Despite this evidence, there is still far from a consensus opinion on the effects of playing football outside the

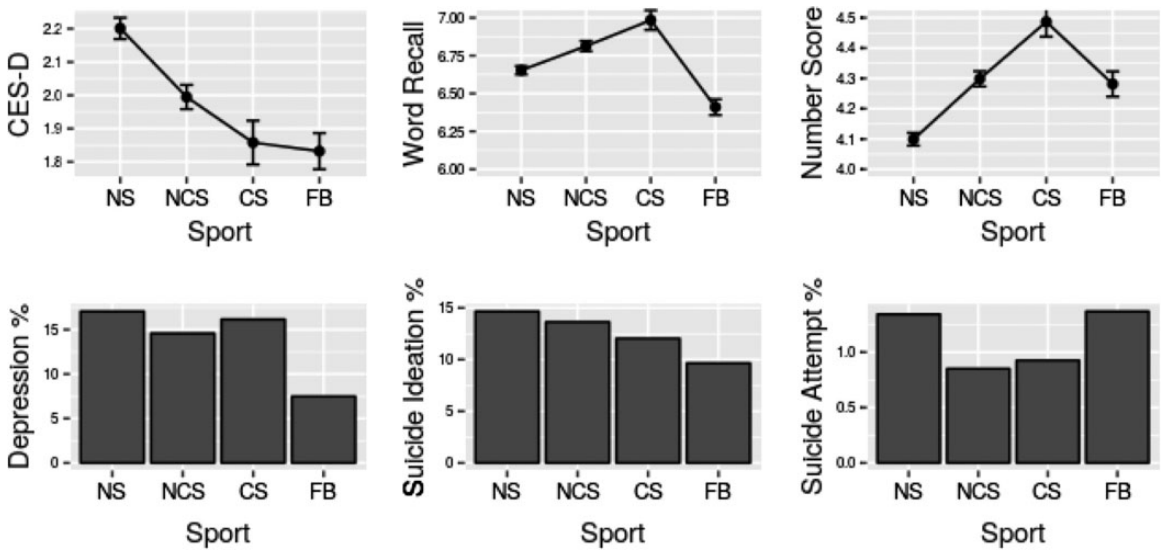

Figure 1. Unadjusted comparison of depressive symptoms, cognition, and suicidality. Add Health study: 1994-2008. CES-D, Center for Epidemiologic Studies Depression Scale; CS, contact sports; FB, football; NCS, noncontact sports only; NS, no sports.

TABLE 2
Generalized Linear Models Predicting Wave IV CES-D, Word Recall, and Number Recall: Add Health Study (1994-2008)[a]

	CES-D (RMSE = 2.088; R^2 = 0.085)		Word Recall (RMSE = 1.879; R^2 = 0.095)		Number Recall (RMSE = 1.424; R^2 = 0.101)	
	b	*P* Value	*b*	*P* Value	*b*	*P* Value
Full sample (n = 10,951)						
Wave I control						
CES-D	0.22	***<.001***				
Standardized Picture Vocabulary Score			0.02	***<.001***	0.02	***<.001***
Actual/intended sports participation						
No sports	0.07	.15	0.01	.77	–0.06	***.04***
Contact sports	0.02	.75	0.01	.82	–0.01	.90
Noncontact sports			Referent			
	CES-D (RMSE = 1.917; R^2 = 0.085)		Word Recall (RMSE = 1.836; R^2 = 0.090)		Number Recall (RMSE = 1.442; R^2 = 0.116)	
	b	*P* Value	*b*	*P* Value	*b*	*P* Value
Males only (n = 5008)						
Wave I control						
CES-D	0.21	***<.001***				
Standardized Picture Vocabulary Score			0.02	***<.001***	0.02	***<.001***
Actual/intended sports participation						
No sports	0.11	.14	–0.04	.51	–0.11	***.04***
Contact sports[b]	0.10	.31	0.07	.48	0.10	.17
Football	–0.02	.79	–0.06	.43	–0.02	.74
Noncontact sports			Referent			

[a]Significant *P* values (<.05) bold and italicized. Trending *P* values (<.10) italicized. CES-D, Center for Epidemiologic Studies Depression Scale; RMSE, root mean square error.
[b]Other than football.

professional game. Adverse later-life outcomes from football have been hypothesized as a result of concussion and subconcussive hits. In fact, studies have shown that the concussion incidence among football, hockey, and rugby players is significantly higher than that of other sports.[20,31] Additionally, head impact exposure in youth football has been described, and cumulative head impacts in a self-selected sample of former collegiate football players were

TABLE 3
Logistic Regression Models Predicting Depression Diagnosis, Suicide Ideation, and Suicide Attempts: Add Health Study (1994-2008)[a]

	Depression			Suicide Ideation			Suicide Attempt		
	OR	95% CI	*P* value	OR	95% CI	*P* value	OR	95% CI	*P* value
Full sample (n = 10,951)									
Wave I control									
CES-D	1.16	1.13-1.18	***<.001***						
Suicide ideation				3.15	2.65-3.74	***<.001***			
Suicide attempt							3.55	2.09-6.03	***<.001***
Actual/intended sport participation									
No sports	1.22	1.07-1.38	***<.01***	1.35	1.13-1.63	***<.01***	1.29	0.83-2.01	.25
Contact sports	0.98	0.82-1.16	.78	1.10	0.86-1.40	.46	1.68	0.97-2.90	*.07*
Noncontact sports					Referent				
Males only (n = 5008)									
Wave I control									
CES-D	1.18	1.13-1.24	***<.001***						
Suicide ideation				3.91	2.94-5.21	***<.001***			
Suicide attempt							3.77	2.23-6.36	***<.001***
Actual/intended sport participation									
No sports	1.24	0.97-1.60	*.09*	1.28	0.92-1.76	.14	1.30	0.83-2.01	.25
Contact sports[b]	1.13	0.80-1.61	.48	1.22	0.77-1.91	.40	1.27	0.59-2.71	.54
Football	0.70	0.52-0.95	***.02***	0.94	0.65-1.36	.74	1.62	0.90-2.90	.11
Noncontact sports					Referent				

[a]Significant *P* values (<.05) bold and italicized. Trending *P* values (<.10) italicized. CES-D, Center for Epidemiologic Studies Depression Scale; OR, odds ratio.
[b]Other than football.

shown to be associated with several of the outcomes for which we did not find an association.[9,29] A recent study found evidence of tauopathy in young athletes in the subacute phase after a severe sports-related head injury.[36] However, it should be noted that, given the constraints of obtaining brains from young athletes, the sample size was extremely small (n = 8). Additionally, a healthy noncontact sport control group was not included for comparison, and multiple potential confounding factors were present in the decedents, including opiate abuse, bipolar disorder, and death by suicide. Finally, death in 3 of the cases occurred within 10 days of severe injury, an interval during which the brain would almost certainly have been recovering from the injury sustained, as concussions of even mild severity require a week of recovery, with symptoms persisting for months or up to 1 year for more severe head injuries.[4,5,32]

Other recent empirical evidence does not support the hypothesis that football participation in high school or college in the absence of concussion may impair cognitive ability or influence depressive symptoms.[6,13,26,28] Broglio et al[6] studied 95 high school football players, observing 101,994 impacts and 20 concussions in 19 athletes. As expected, athletes experienced cognitive decline in the acute recovery period from concussion, but only 1 of the nearly 100 comparisons between impact exposure variables and cognitive function achieved statistical significance. Similarly, in a study of 46 collegiate football players, Gysland et al[13] did not observe that impaired performance on Automated Neuropsychological Assessment Metrics, the Standardized Assessment of Concussion, balance, or total symptom severity were associated with any of the multiple impact exposure variables. Miller et al[28] assessed 76 collegiate football players using the Standardized Assessment of Concussion (SAC) and Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) at preseason, midseason, and postseason and did not observe significant performance declines in athletes with regard to the impact variables measured. Finally, Meehan et al[26] reported associations between Division III football players with a history of concussion and adverse cognitive and emotional outcomes later in life. However, removing players with a history of concussion from the analysis caused the associations to become nonsignificant, suggesting that the subconcussive hits mechanism did not cause later-life impairment or emotional problems. Furthermore, many of the concussion cases were self-reported undiagnosed concussions, which could have been subject to recall bias.

In addition to these studies on former football players, studies on former soccer players do not support the hypothesis that subconcussive hits may cause later-life cognitive decline. Although concussion in soccer is not as common as it is in football, heading is a common element of the game. Former soccer players who continued to play recreationally were shown to have similar cognitive ability to matched nonsport participants.[19,37] However, these studies were able to associate cortical thickness in the parietal and occipital areas with estimates of cumulative heading exposure. Given these conflicting results, we should note that the measurement of a subconcussive blow is itself an issue of debate. Specifically, the frequency, timing, force, number, and location and direction of the blow can all influence the

TABLE 4
Coefficients (*b*) and ORs of Model Covariates: Add Health Study (1994-2008)[a]

	Depression		Suicide Ideation		Suicide Attempts		CES-D		Word Recall		Number Recall	
	OR	*P* Value	OR	*P* Value	OR	*P* Value	*b*	*P* Value	*b*	*P* Value	*b*	*P* Value
Full sample (n = 10,951)												
Sex	2.25	***<.001***	1.15	.11	1.38	.12	0.21	***<.001***	0.51	***<.001***	–0.10	***<.001***
Age												
Wave I	1.08	.41	0.92	.51	1.01	.99	–0.08	.20	–0.09	.44	–0.09	***.04***
Wave IV	0.89	.20	1.04	.76	1.00	.97	0.05	.43	0.04	.12	0.06	.18
Race												
African American	0.38	***<.001***	0.86	.16	0.80	.36	0.31	***<.001***	–0.32	***<.001***	–0.13	***<.001***
Hispanic	0.40	***<.001***	0.71	***.01***	0.82	.45	–0.08	.20	–0.16	***<.01***	–0.01	.85
Native American	1.12	.67	1.19	.66	1.32	.71	0.08	.73	–0.41	*.05*	–0.36	***.02***
Asian	0.32	***<.001***	0.85	.37	0.61	.35	0.26	***<.01***	–0.33	***<.001***	0.01	.87
Missing	0.48	.33	1.36	.68	0.00	.98	–0.71	.10	–0.56	.16	0.45	.13
White						Referent						
Education												
Less than high school	1.64	***<.001***	2.28	***<.001***	4.04	***<.001***	1.06	***<.001***	–1.02	***<.001***	–0.63	***<.001***
High school	1.38	***<.01***	1.48	***.01***	2.85	***<.01***	0.52	***<.001***	–0.70	***<.001***	–0.46	***<.001***
Some college	1.57	***<.001***	1.66	***<.001***	1.61	.12	0.35	***<.001***	–0.35	***<.001***	–0.23	***<.001***
Post grad/baccalaureate	0.77	***.04***	0.93	.68	0.20	.12	–0.10	.19	0.17	***.02***	0.12	***.03***
Missing	0.00	.97	0.00	.97	0.00	.99	–0.39	.85	1.23	.51	0.52	.72
College grad						Referent						
Males only (n = 5008)												
Age												
Wave I	1.36	*.06*	0.76	.17	1.04	.90	–0.04	.63	–0.08	.32	–0.11	*.08*
Wave IV	0.73	*.05*	1.28	.19	0.96	.90	0.02	.82	0.04	.66	0.08	.24
Race												
African American	0.41	***<.001***	0.51	***<.001***	0.82	.41	0.34	***<.001***	–0.26	***<.001***	–0.20	***<.001***
Hispanic	0.38	***<.001***	0.70	*.07*	0.81	.43	–0.08	.33	0.03	.74	–0.06	.38
Native American	0.38	.19	1.57	.41	1.34	.69	–0.21	.52	–0.03	.93	–0.52	***.03***
Asian	0.31	***<.001***	0.63	.11	0.61	.34	0.29	***.01***	–0.43	***<.001***	–0.03	.72
Missing	0.52	.53	1.26	.83	0.00	.98	–0.66	.19	–0.34	.48	0.10	.79
White						Referent						
Education												
Less than high school	1.41	.14	3.09	***<.001***	3.77	***<.001***	0.80	***<.001***	–0.93	***<.001***	–0.58	***<.001***
High school	1.24	.25	1.76	***.02***	2.71	***<.01***	0.42	***<.001***	–0.68	***<.001***	–0.47	***<.001***
Some college	1.73	***<.001***	2.05	***<.001***	1.57	.13	0.21	***<.01***	–0.29	***<.001***	–0.19	***<.001***
Post grad/baccalaureate	1.05	.85	0.99	.98	0.21	.13	–0.16	.18	0.31	***<.01***	0.15	*.09*
Missing	0.00	.98	0.00	.98	0.00	.99	–0.56	.77	1.11	.55	0.58	.69
College grad						Referent						

[a]Significant *P* values (<.05) bold and italicized. Trending *P* values (<.10) italicized. CES-D, Center for Epidemiologic Studies Depression Scale; OR, odds ratio.

severity of head injuries and likely the effect of subconcussive blows.

There are several important limitations of our study to keep in mind when considering the results. Add Health has only a onetime measure of sport participation, and it is *intended* sport participation. Furthermore, this snapshot of participation does not inform about the duration of participation during adolescence, and there are no data in Add Health regarding position played, concussions sustained, or quantification of head impacts that could affect long-term cognitive and mental health. Although a more precise measure of sport participation is desirable, using intended participation instead of actual participation would bias our results only if individuals of higher cognitive ability and lower depressive symptoms systematically answered that they intended to participate in contact sports and then did not. In addition, it appears that our estimate of sport participation is in line with overall sport participation for young adults during the period. A 2015 data bank study from Child Trends[7] reported sport participation rates of 69% and 65% for male 10th and 12th graders and 52% and 50% for female 10th and 12th graders during 1991. W1 data instruments were administered to 7th- to 12th-grade students during the 1994-1995 school year. Our observed rates of sport participation approximate these trends, with 62.3% of males and 46.5% of females in our sample classified as sport participants. Finally, we tested if intended sport participation from the W1 in-school interview was associated with other measures of sport participation from W1 and W2. Participants were asked, "During the past week, how many times did you play an active sport, such as baseball, softball, basketball, soccer, swimming, or football?" We used χ^2 tests of association to test the relationship

between intended sport participation and frequency of playing these sports at W1 and W2 and observed a highly significant association at both W1 ($\chi^2 = 1007.4, P < .001$) and W2 ($\chi^2 = 696.2, P < .001$).

Another limitation is the age at which follow-up occurred. The participants were in their late 20s to early 30s at follow-up (W4). As such, it could be possible that we did not detect any cognitive decline as a result of participation in sport because W4 participants were too young to detect it and the development of cognitive decline and/or depression had yet to emerge. It will be important that this question be addressed throughout the subsequent waves of Add Health going forward.

It is also important to consider that those who intended to participate in contact sports during W1 of the study may have been more likely to select out of the sample by W4. Accordingly, those with the greatest risk of head injury and subsequent complications may be the least likely to participate for the full study. However, results from ancillary analysis suggest that selection out of the study by W4 was not related to sport participation.

We attempted to adjust for early-life cognitive ability, depressive symptoms, and suicidality by including proxies for these variables from W1 as controls in our models. However, depression diagnosis was not measured at W1, so W1 CES-D score was used as a control. Additionally, cognitive tests differed between W1 and W4. However, given the overall consistency of the results of the models and the fact that the proxies were consistently strong predictors of W4 outcomes, we believe that we adequately controlled for baseline approximations of these variables.

Finally, in ancillary analyses (results available upon request), we evaluated comparable models but took advantage of the sibling pairs component of the Add Health study.[15] Specifically, we examined 122 male sibling pairs and 4 male trios who were discordant for football participation. We then evaluated a fixed-effects regression model in which observations were clustered within families, and our results were consistent with the full-sample estimates; 2-tailed P values were all $>.7$. This information, coupled with the results presented earlier, provides further evidence that actual/intended sports participation in adolescence is not adversely associated with our measures of cognition and mental health evaluated in the current study.

Our findings supported the hypothesis that intended participation in contact sports was not associated with impaired cognition or depressive symptoms in early adulthood. Our research contributes to a growing field investigating sports participation of the typical youth football player as opposed to former professionals. Furthermore, few current public health issues are as contentious and controversial as the safety and consequences of participation in football. This controversy highlights the need for more rigorous research to gain a better understanding of the risks and mechanism of injury associated with youth sport participation. Research insights on the risks of participation weighed with the risks of not participating in sports—coupled with rule, policy, and legislative changes to make participation safer—will enable parents and young athletes to make educated, informed decisions based on solid evidence.

CONCLUSION

Intended participation in contact sports was not associated with impaired cognitive or mental health in a cohort of young adults from the Add Health study. Further research with subsequent waves of data from this cohort is warranted to determine if this lack of association persists into middle and late adulthood. Finally, improved measures of sport participation, including position played, duration of play, and head injuries suffered, would provide a more precise construct of the exposure of contact sports during adolescence.

ACKNOWLEDGMENT

The authors thank the University of Colorado Boulder Libraries Open Access Fund for its financial support in publishing this article. This research uses data from Add Health, a program project directed by Kathleen Mullan Harris and designed by J. Richard Udry, Peter S. Bearman, and Kathleen Mullan Harris at the University of North Carolina at Chapel Hill and funded by grant P01-HD31921 from the Eunice Kennedy Shriver National Institute of Child Health and Human Development, with cooperative funding from 23 other federal agencies and foundations. Special acknowledgment is due Ronald R. Rindfuss and Barbara Entwisle for assistance in the original design. Information on how to obtain the Add Health data files is available on the Add Health website (http://www.cpc.unc.edu/addhealth). No direct support was received from grant P01-HD31921 for this analysis.

REFERENCES

1. Alosco ML, Mez J, Tripodis Y, et al. Age of first exposure to tackle football and chronic traumatic encephalopathy. *Ann Neurol*. 2018;83(5):886-901.
2. Bachynski KE. Tolerable risks? Physicians and youth tackle football. *N Engl J Med*. 2016;374(5):405-407.
3. Baron SL, Hein MJ, Lehman E, Gersic CM. Body mass index, playing position, race, and the cardiovascular mortality of retired professional football players. *Am J Cardiol*. 2012;109(6):889-896.
4. Belanger HG, Vanderploeg RD. The neuropsychological impact of sports-related concussion: a meta-analysis. *J Int Neuropsychol Soc*. 2005;11(4):345-357.
5. Bigler ED. Neuropsychology and clinical neuroscience of persistent post-concussive syndrome. *J Int Neuropsychol Soc*. 2008;14(1):1-22.
6. Broglio SP, Eckner JT, Martini D, Sosnoff JJ, Kutcher JS, Randolph C. Cumulative head impact burden in high school football. *J Neurotrauma*. 2011;28(10):2069-2078.
7. Child Trends Data Bank. Participation in school athletics. https://www.childtrends.org/indicators/participation-in-school-athletics. Accessed August 28, 2018.
8. Chung J, Cummings P, Samadani U. Does CTE call for an end to youth tackle football? *Star Tribune*. February 10, 2018.
9. Daniel RW, Rowson S, Duma SM. Head impact exposure in youth football. *Ann Biomed Eng*. 2012;40(4):976-981.
10. Deshpande SK, Hasegawa RB, Rabinowitz AR, et al. Association of playing high school football with cognition and mental health later in life. *JAMA Neurol*. 2017;74(8):909-918.
11. Guskiewicz KM, Marshall SW, Bailes J, et al. Association between recurrent concussion and late-life cognitive impairment in retired professional football players. *Neurosurgery*. 2005;57(4):719-726.

12. Guskiewicz KM, Marshall SW, Bailes J, et al. Recurrent concussion and risk of depression in retired professional football players. *Med Sci Sports Exerc*. 2007;39(6):903-909.
13. Gysland SM, Mihalik JP, Register-Mihalik JK, Trulock SC, Shields EW, Guskiewicz KM. The relationship between subconcussive impacts and concussion history on clinical measures of neurologic function in collegiate football players. *Ann Biomed Eng*. 2012;40(1):14-22.
14. Harris KM. *The National Longitudinal Study of Adolescent Health (Add Health), waves I and II, 1994-1996; wave III, 2001-2002; wave IV, 2007-2009* [machine-readable data file and documentation]. Chapel Hill, NC: Carolina Population Center, University of North Carolina at Chapel Hill; 2009.
15. Harris KM, Halpern CT, Haberstick BC, Smolen A. The National Longitudinal Study of Adolescent Health (Add Health) sibling pairs data. *Twin Res Hum Genet*. 2013;16(1):391-398.
16. Hart J Jr, Kraut MA, Womack KB, et al. Neuroimaging of cognitive dysfunction and depression in aging retired National Football League players: a cross-sectional study. *JAMA Neurol*. 2013;70(3):326-335.
17. Janssen PH, Mandrekar J, Mielke MM, et al. High school football and late-life risk of neurodegenerative syndromes, 1956-1970. *Mayo Clin Proc*. 2017;92(1):66-71.
18. Kahn NF, Halpern CT. The relationship between cognitive ability and experiences of vaginal, oral, and anal sex in the United States. *J Sex Res*. 2018;55(1):99-105.
19. Koerte IK, Mayinger M, Muehlmann M, et al. Cortical thinning in former professional soccer players. *Brain Imaging Behav*. 2016;10(3):792-798.
20. Koh JO, Cassidy JD, Watkinson EJ. Incidence of concussion in contact sports: a systematic review of the evidence. *Brain Inj*. 2003; 17(10):901-917.
21. Lawrence EM. Why do college graduates behave more healthfully than those who are less educated? *J Health Soc Behav*. 2017;58(3):291-306.
22. Lehman EJ, Hein MJ, Gersic CM. Suicide mortality among retired National Football League players who played 5 or more seasons. *Am J Sports Med*. 2016;44(10):2486-2491.
23. Manley G, Gardner AJ, Schneider KJ, et al. A systematic review of potential long-term effects of sport-related concussion. *Br J Sports Med*. 2017;51(12):969-977.
24. Mays D, Depadilla L, Thompson NJ, Kushner HI, Windle M. Sports participation and problem alcohol use: a multi-wave national sample of adolescents. *Am J Prev Med*. 2010;38(5):491-498.
25. McCrory P, Meeuwisse WH, Kutcher JS, Jordan BD, Gardner A. What is the evidence for chronic concussion-related changes in retired athletes: behavioural, pathological and clinical outcomes? *Br J Sports Med*. 2013;47(5):327-330.
26. Meehan WP 3rd, Taylor AM, Berkner P, et al. Division III collision sports are not associated with neurobehavioral quality of life. *J Neurotrauma*. 2016;33(2):254-259.
27. Miles SH, Prasad S. Medical ethics and school football. *Am J Bioeth*. 2016;16(1):6-10.
28. Miller JR, Adamson GJ, Pink MM, Sweet JC. Comparison of preseason, midseason, and postseason neurocognitive scores in uninjured collegiate football players. *Am J Sports Med*. 2007;35(8):1284-1288.
29. Montenigro PH, Alosco ML, Martin BM, et al. Cumulative head impact exposure predicts later-life depression, apathy, executive dysfunction, and cognitive impairment in former high school and college football players. *J Neurotrauma*. 2017;34(2):328-340.
30. Perreira KM, Deeb-Sossa N, Mullan Harris K, Bollen K. What are we measuring? An evaluation of the CES-D across race/ethnicity and immigrant generation. *Social Forces*. 2005;83(4):1567-1601.
31. Pfister T, Pfister K, Hagel B, Ghali WA, Ronksley PE. The incidence of concussion in youth sports: a systematic review and meta-analysis. *Br J Sports Med*. 2016;50(5):292-297.
32. Ponsford J, Willmott C, Rothwell A, et al. Factors influencing outcome following mild traumatic brain injury in adults. *J Int Neuropsychol Soc*. 2000;6(5):568-579.
33. Radloff LS. The CES-D scale: a self-report depression scale for research in the general population. *Appl Psychol Meas*. 1977;1:385-401.
34. RStudio Team. *RStudio: Integrated Development for R*. Boston, MA: RStudio Inc; 2016.
35. Savica R, Parisi JE, Wold LE, Josephs KA, Ahlskog JE. High school football and risk of neurodegeneration: a community-based study. *Mayo Clin Proc*. 2012;87(4):335-340.
36. Tagge CA, Fisher AM, Minaeva OV, et al. Concussion, microvascular injury, and early tauopathy in young athletes after impact head injury and an impact concussion mouse model. *Brain*. 2018;141(2):422-458.
37. Vann Jones SA, Breakey RW, Evans PJ. Heading in football, long-term cognitive decline and dementia: evidence from screening retired professional footballers. *Br J Sports Med*. 2014;48(2):159-161.

APPENDIX

Source Variables

Source variables for covariates and socioeconomic status measures are available in Appendix Table A1.

CES-D: Construction and Analysis of Invariance

Participants were asked to what degree the following were true during the past 7 days: "You felt depressed"; "You felt sad"; "You could not shake off the blues, even with help from your family and your friends"; "You felt happy." Participants scored each using the following scale: 0, never or rarely; 1, sometimes; 2, a lot of the time; 3, all of the time. Happy is inversely recoded such that 3 becomes 0, 2 becomes 1, 1 becomes 2, and 0 becomes 3. The sum of the scores from each question provides a composite score ranging from 0 to 12, with higher scores indicating greater depressive symptoms. Although the validity of this metric to perform across racial/ethnic groups has been demonstrated, we were concerned about its validity when looking across waves of the Add Health study. As such, tests of invariance were performed comparing the CES-D from W1 to W4.

Analysis of invariance was done with the R package "lavaan." A model was first fit with all 4 questions as predictors. Factor loadings, χ^2, root mean square error of approximation, standardized root mean residual, and comparative fit index were measured for all groups, W1 only, and W4 only. Next, the same statistics were calculated by placing configural invariance, metric invariance, and scalar invariance restrictions on the model. The results of the invariance tests are presented in Appendix Table A2. Invariance was determined if the change in comparative fit index was <0.01, which is consistent with several previous studies and appropriate for a sample of this size.[1] The results of this analysis suggest that CES-D metrics for W1 and W4 were invariant.

APPENDIX REFERENCE

1. Putnick DL, Bornstein MH. Measurement invariance conventions and reporting: the state of the art and future directions for psychological research. *Dev Rev*. 2016;41:71-90.

TABLE A1
Source Variables and Descriptions for Participant Sport, Demographic, Depressive Symptoms, and Cognitive Ability Metrics: Add Health Study (1994-2008)

Source Variable	Description
AID	ID
BIO_SEX	Biological sex
AGE_W4	Age at wave IV
AH_Race	Race
S44A18	In the coming year, do you intend to participate in baseball? Are you participating / Do you plan to participate in the following clubs, organizations, and teams (check all that apply): baseball/softball
S44A19	In the coming year, do you intend to participate in baseball? Are you participating / Do you plan to participate in the following clubs, organizations, and teams (check all that apply): basketball
S44A20	Are you participating / Do you plan to participate in the following clubs, organizations, and teams (check all that apply): field hockey
S44A21	Are you participating / Do you plan to participate in the following clubs, organizations, and teams (check all that apply): football
S44A22	Are you participating / Do you plan to participate in the following clubs, organizations, and teams (check all that apply): ice hockey
S44A23	Are you participating / Do you plan to participate in the following clubs, organizations, and teams (check all that apply): soccer
S44A24	Are you participating / Do you plan to participate in the following clubs, organizations, and teams (check all that apply): swimming
S44A25	Are you participating / Do you plan to participate in the following clubs, organizations, and teams (check all that apply): tennis
S44A26	Are you participating / Do you plan to participate in the following clubs, organizations, and teams (check all that apply): track
S44A27	Are you participating / Do you plan to participate in the following clubs, organizations, and teams (check all that apply): volleyball
S44A28	Are you participating / Do you plan to participate in the following clubs, organizations, and teams (check all that apply): wrestling
S44A29	Are you participating / Do you plan to participate in the following clubs, organizations, and teams (check all that apply): other sport
H1FS6	Wave I: How often was the following true during the past 7 days? You felt depressed.
H1FS16	Wave I: How often was the following true during the past 7 days? You felt sad.
H1FS3	Wave I: How often was the following true during the past 7 days? You could not shake off the blues, even with help from your family and your friends.
H1FS11	Wave I: How often was the following true during the past 7 days? You felt happy.
H4MH22	Wave IV: How often was the following true during the past 7 days? You felt depressed.
H4MH26	Wave IV: How often was the following true during the past 7 days? You felt sad.
H4MH19	Wave IV: How often was the following true during the past 7 days? You could not shake off the blues, even with help from your family and your friends.
H4MH24	Wave IV: How often was the following true during the past 7 days? You felt happy.
H4ID5H	Wave IV: Has a doctor, nurse or other health care provider ever told you that you have or had: depression?
H1SU1	Wave I: During the past 12 months, did you ever seriously think about committing suicide?
H4SE1	Wave IV: During the past 12 months, have you ever seriously thought about committing suicide?
H1SU2	Wave I: During the past 12 months, how many times did you actually attempt suicide?
H4SE2	Wave IV: During the past 12 months, how many times have you actually attempted suicide?
C4WD90_1	How many total words on the word list did the respondent remember during the 90-second recall period?
C4NUMSCR	Total score on number recall task
AH_PVT	Add Health Picture Vocabulary Test standardized score
H4ED2	Participant: What is the highest level of education that you have achieved to date?
PA12	Parent: How far did you go in school?
PB8	Parent: How far did your current (spouse/partner) go in school?
TAC09051	Proportion of individuals 25 or older with a college degree

TABLE A2
Results of Test of Invariance Between Wave I and Wave IV CED-D: Add Health Study (1994-2008)[a]

Model	χ^2 (*df*)	RMSEA	SRMR	CFI	Change in CFI
All groups	72.085 (2)	0.031	0.006	0.998	—
Wave I	18.793 (2)	0.020	0.004	0.999	—
Wave IV	65.363 (2)	0.045	0.008	0.997	—
Configural variance	84.156 (4)	0.033	0.006	0.998	—
Metric invariance	458.391 (7)	0.060	0.036	0.990	0.008
Scalar invariance	788.18 (10)	0.065	0.040	0.983	0.007

[a]CED-D, Center for Epidemiologic Studies Depression Scale; CFI, comparative fit index; RMSEA, root mean square error of approximation; SRMR, standardized root mean residual.

TABLE A3
Conversion of ORs to RRs for Binary Outcomes[a]

	Depression		Suicide Ideation		Suicide Attempt	
	OR	RR	OR	RR	OR	RR
Full sample (n = 10,951)						
No sports	1.219	1.181	1.355	1.329	1.294	1.005
Contact sports	0.976	0.979	1.097	1.091	1.676	1.008
Noncontact sports	Referent					
Males only (n = 5008)						
No sports	1.245	1.219	1.275	1.258	1.295	1.293
Contact sports[b]	1.135	1.122	1.215	1.203	1.266	1.265
Football	0.7	0.718	0.94	0.942	1.617	1.611
Noncontact sports	Referent					

[a]OR, odds ratio; RR, risk ratio.
[b]Other than football.

TABLE A4
Sport Participation Distribution for Participants at Waves I and IV and Results of Goodness-of-Fit Test[a]

	Sport Participation Distribution, %				GPA		
	Wave I	Wave IV	χ^2 (*df*)	*P*	Wave I	Wave IV	*P*
No sport	46.7	46.5	3.08 (3)	.38	2.49	2.51	.49
Noncontact sport	31.4	32.0			2.77	2.80	.25
Contact sport	8.7	8.7			2.85	2.87	.68
Football	13.2	12.7			2.48	2.49	.76

[a]GPA, grade point average.

TABLE A5
Results of Logistic Regression Model Predicting Selection Out of Study by Wave IV as a Function of Sport Participation[a]

	Odds Ratio	*P*
Sex	0.80	***.01***
Age: wave I	1.02	.36
Race		
African American	1.44	***<.001***
Hispanic	1.02	.88
Native American	0.63	.43
Asian	1.70	***<.001***
Missing	1.97	.28
White	Referent	
Education		
Less than high school	1.98	***<.001***
High school	1.36	***.02***
Some college	1.27	***.02***
College grad	1.39	*.06*
Post grad/baccalaureate	1.08	.65
Actual/intended sport participation		
No sports	1.11	.23
Contact sports	0.96	.73
Noncontact sports	Referent	

[a]Significant *P* values (<.05) bold and italicized. Trending *P* values (<.10) italicized.